SIMULATION SYSTEM, METHOD AND COMPUTER-READABLE MEDIUM FOR HUMAN AUGMENTATION DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of U.S. provisional applications No. 60/330,689 filed on Oct. 29, 2001 and No. 60/333,753 filed on Nov. 29, 2001.

FIELD OF THE INVENTION

[0002] The present invention relates to a simulation system, a simulation method and a computer-readable medium for analysis, and synthesis of human motion under partial assist from powered augmentation devices.

BACKGROUND OF THE INVENTION

[0003] Effective usage of human assistive systems or augmentation devices for restoration or enhancement of motor function is an important area of research in rehabilitation and performance enhancement. A partial list of important and desired features of an effective assistive system include: (1) a decrease in energy rate and cost with respect to able-bodied subjects performing the same task, (2) minimum disruption and maximum comfort of normal activities when employing the assistive system, and (3) practicality.

[0004] The third requirement considers the ease of wearing such a device and its power consumption needs. These requirements and available technology have led to the development of externally powered orthoses and prostheses that interface directly or indirectly with the human neuromuscular system. Although significant progress has been made in meeting many of the requirements needed for development of practical human assist devices (Popovic, D., Externally Powered and Controlled Orthotics and Prosthetics. The Biomedical Engineering Handbook, Editor Bronzino, J. D., 2nd ed. Vol. 2, Chapter 142, 2000), realization of such systems for daily applications is still in its infancy. The complexity of the central nervous system (CNS) control and the interface between voluntary control and external artificial control are still challenging, unanswered questions.

[0005] At Honda's Wako Research Center, a mechanically powered walking assist prototype system was recently unveiled (Katoh and Hirata, The Concept of a Walking Assistance Suit, Welfare Engineering Symposium, The Japan Society of Mechanical Engineers, August 2001). The target application is to help the elderly and disabled people to either execute daily tasks they could not previously perform, or use less physical exertion than they currently employ for these tasks. The tasks considered include walking, lifting, sitting/standing, and climbing stairs. Two important and challenging questions to consider in the implementation of the Honda prototype and similar human augmentation systems include: 1) analysis and monitoring of biomechanical as well as physiological quantities which cannot be readily measured and 2) the synthesis of an active control which can safely and effectively augment voluntary control. By developing computational methods to study these issues, future performance of human augmentation devices can be studied through simulation, without constraints imposed by hardware implementations of current technology. Simulation studies also enable us to estimate physiological quantities that cannot be easily measured, including muscle forces, joint forces, and energetics of motion. We can simulate effects of aging, predict muscular activity, estimate muscle fatigue and capacity, and detect potential dangerous physiological conditions. It should be mentioned that the exclusive use of simulation is not a substitute for eventual testing on live human subjects. However, an accurate subject-specific simulation allows control algorithms to be designed and refined for the walking assist device. This is especially relevant in our target user population because they already have existing health constraints.

[0006] U.S. Pat. No. 6,152,890 discloses a device and a method for the recording, presentation and automatic classification of biomechanical variables measured on a freely moving test person during a work shift.

[0007] Japanese patent publication unexamined No. 2000-249570 discloses a method for generating human kinematic data.

[0008] "Gruber, K. et. al., 1998. A comparative study of impact dynamics: wobbling mass model versus rigid body models. Journal of Biomechanics 31, 439-444" discloses inverse dynamics model used to simulate the human body.

[0009] However, any of the above documents does not deal with analysis and synthesis of human motion under assist from powered augmentation devices.

[0010] Accordingly, what is needed is a system and a method for analysis and synthesis of human motion under assist from powered augmentation devices.

SUMMARY OF THE INVENTION

[0011] According to one aspect of the invention, a simulation system is provided for a combined musculoskeletal and augmentation device system including segments and joints connecting the segments. The simulation system comprises a dynamics model of the combined musculoskeletal and augmentation device system and an augmentation device controller for control of the augmentation device. The simulation system further comprises an inverse dynamics model for the musculoskeletal and augmentation device system and a muscle force and muscle capacity module for checking and adjusting the computed torques. The dynamics model of the combined musculoskeletal and augmentation device system receives feasible computed torques at the joints as inputs and delivers simulated kinematic data of the segments as outputs. The augmentation device controller for control of the augmentation device, receives the simulated kinematic data as inputs and delivers assist torques as outputs. The inverse dynamics model for the musculoskeletal and augmentation device system, receives the simulated kinematic data, desired kinematic data of the segments and the assist torques as inputs and delivers the computed muscle torques and net joint torque as outputs. The muscle force and muscle capacity module for checking and adjusting the computed torques, receives the computed muscle torques as inputs and delivers feasible computed torques as outputs after making adjustments to the computed torques.

[0012] According to another aspect of the invention, a method is provided for simulating a combined musculoskeletal and augmentation device system including segments and joints connecting the segments. The method comprises